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The application of virtual reality technology in medical education and training

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Abstract

The development of virtual reality (VR) technology has greatly changed various industries, and medicine field is not exceptional too. This paper briefly introduces application of VR from two aspects. The application in theoretical teaching is virtual anatomy and virtual human projects have been widely researched in various universities and institutions all over the world, which will give medical students a more realistic visual sense compared to the traditional teaching methods with 2-D diagrams. And VR surgical system plays an important role in clinical practice training, which provides surgeons a simulation environment with vivid visual, auditory, haptic senses, it will be an excellent substitute of cadaver because residents and interns can repeat all kinds of operations in the system without limits.

Keywords: Virtual reality, education, technology, computer.

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1. Introduction

Virtual reality (VR) is a hot area of current research in various industries. Based on computer graphics, computer vision, multimedia technology, sensor technology, simulation technology, optics, kinematics and other relevant scientific technologies, VR generates a 3-D simulation world which offers users high immersive senses of vision, audition, olfaction and tactility; and operators can interact with virtual objects in the world in a natural way with the help of necessary equipment. VR, therefore, can be considered as an advanced human–computer interaction interface.

VR technology first came out in the 1960s, and the concrete concept was proposed in the 1980s. With the rapid development of scientific technology and social progress, more and more researchers in various industries have a strong interest in VR, the technology has been widely applied in many fields such as education, medicine, military area, industry simulation, entertainment, games and so on. For instance, the SIMNET virtual battlefield system developed by the United States Department of Defense and the US Military is utilised for tank cooperative training; likewise surgeons use the virtual surgery system to replace the cadaver and model for operation training.

This paper will briefly introduce the applications of VR in medical education domain from two aspects of theoretical teaching and clinical practice training.

2. Application of VR in medicine

VR technology has always had very important practical significance in medical application. As early as in 1993, Helsel and Doherty (1993) had detailed statistics on the VR projects around the world, the results showed there were a total of 805 VR projects, and 49 of them are medical VR systems, which accounted for 6.13%. Over the years, the number and proportion of medical VR applications has been gradually rising.

Nowadays, the applications range of VR in medicine covers medical imaging, medical simulation, virtual anatomy, medical education, telemedicine and so on.

2.1. Application of VR in medical education

Virtual anatomy is a typical application of VR in medical education. In the traditional education, teachers usually use illustrations to assist lecture in the classroom, most of the illustrations are just 2-D pictures and photos, which are not vivid and quite difficult to understand. The virtual anatomic atlas consists of digital anatomical diagrams, where students can select any virtual observation object of human body and move it freely, even the virtual organs can give users real-time sensory feedback to help them to understand body structure.

The most significant application of virtual anatomy is ‘virtual human’, it refers to process the information of human morphology, human biology and human physics by computers and establish a digital virtual body to replace real human body in experiments and research studies. To get accurate data, researchers choose a cadaver and cut it into extremely thin pieces, then they use digital camera and scanner to take a picture of each piece, analyse the images and store them in computers, finally, the 3-D stereoscopic virtual human has been constructed.

The earliest visual human was born in America, in 1993, National Library of Medicine started a programme named ‘Visual Human Projects’ (VHPs) (Spitzer & Whitlock, 1998), medical college of Colorado State University used CT and MRI to implement full body scans and Monte Carlo simulations of a man’s cadaver and a woman’s cadaver separately (Ackerman, 1999; Spitzer, Ackerman, Scherzinger & Whitlock, 1996), the VHP dataset was made into CD and released in 1995. There were 1,878 pieces of man’s cross section and distance between every two pieces is 1.0 mm, total size of man’s sections is 15 GB, and there were 5,190 pieces of woman’s cross section, the distance is

0.33 mm, total size is 43 GB. Medical students can use these data for study and training, they can enlarge images to observe local details and complete training of coronal plane and vertical plane anatomy in computers.

The advent of VHP immediately drew much attention of experts and researchers in many countries. University of Asian Medicine in South Korea made 'Visible Korea Human' programme (Chung & Kim, 2000) under the funding of Korea Institute of Technology Information, the dataset of a man's cadaver was established in 2000, which included 8,590 pieces of sections, and the total size is 153.73 GB. This is the world first human body dataset with the features of oriental race. The UK, Italy, Singapore, Japan and other countries then started the research of VHP and established VHP mirror sites. At present, many famous institutions over the world have conducted many research studies and applications about VHP data collection, for instance, Harvard University finished brain atlas establishment and surgical planning research, Stanford University applied the dataset to explore virtual flight cockpit and virtual endoscope system, laboratories in the Boston area constructed human brain model and developed virtual ear speculum, the University of Washington made Digital Anatomist Project, NASA Biocomputing Center and Sapporo Medical University of Japan also implemented the collection of human dataset (Wang & Gui, 1999).

'Chinese Digital Virtual Human Body Program' was started in 2002 based on National High Technology Research and Development Program ('863' Program) of China. In March 2002, the Third Military Medical University accomplished the collection of the first set of Chinese man and woman visual human digital data (Luo, 2002; Zhang et al., 2003), anatomists from Shanghai, Chongqing and Guangzhou provided six datasets of different sexes, the experts and researchers from University of Hong Kong, Beijing Tongren Hospital, Fudan University, Tsinghua University and many other institutions worked together and had developed various application software based on the datasets.

2.2. Virtual surgery simulation system

Virtual surgery simulation system (VSSS) is a significant research direction in the field of medical VR. In traditional medical education, residents use cadaver or anthropometric dummy to practice operations, which have great difference from the living body in actual operation and can't suit the need of surgeons. In VSSS, human organs are reconstructed in three dimensions based on the real CT and MRI images, which simulate physiological and physical reaction of human body to provide a reusable virtual platform for training resident and interns. The first VSSS in the world was explored by Delp et al. (1990) in 1980s for observing the procedure and result of joint transplantation operation, however, the surgery simulation system had little realities and no interactive manipulation. In 1997, Delp, Loan, Basdogan, Buchanan and Rosen (1995) utilised dataset of virtual 'Visible Human' to construct injured leg model according to anatomical and physiological features, and established a surgery simulation system with stereoscopic display function. This system simulated tissue deformation, cutting, bleeding, haemostasis and other operation procedures. Although it had many imperfections constrained with technologies then, the system still made great sense for validating the feasibility of virtual surgery simulation.

At the present stage, the common VSSS fall into three categories:

1. virtual injection simulation system

This kind of system usually has simple structures and low cost, and the visual fidelity and force feedback degree of freedom is relatively weak. These systems have been widely applied, and even replace the real objects as the new means of training in some cases. For instance, the researchers in University of California, Berkeley developed a virtual injection system applied in radiosurgery (Alterovitz, Goldberg, Pouliot & Taschereau, 2003), it was used to make plans for brachytherapy surgery and carry on training in advance. In 2012, Manoharan, Gerwen, Dobbelsteen and Dankelman (2012) in

Delft University of Technology in the Netherland developed a virtual system with two degree of freedom for training vertebral puncture.

2. virtual endoscope emulator

Compared to the above systems, this kind of emulator has been able to provide relatively vivid visual effects. These systems can simulate the real-time deformation of human body and organs, but mainly adopt simplified mechanical mode such as mass-spring model, so the training effectiveness is constrained by the low precision of tissue deformation simulation. There are several representative emulators, for instance, the LASSO virtual laparoscope system (Szekely et al., 2000) developed by ETH Zurich which adopted finite element method to simulate real-time deformation of soft tissues. KISMET virtual surgical framework developed by University Karlsruhe in German and FZK virtual endoscopy training system (Szekely et al., 2000) developed by Kuhnapfel et al. based on KISMET system. In China, the research team in Zhejiang University developed a virtual gastrointestinal endoscopy training system (He, Xiao & Li, 2007) combined real endoscopic instruments and various electromechanical control methods, which provided a vivid simulation environment of endoscopic surgery, the surgeons can enhance their abilities of direction cognition and hand-eye coordination by using the system.

3. virtual open surgery emulator

This kind of emulator involves various techniques including force feedback, real-time deformation simulation, soft tissue cutting simulation, VR display and so on. Therefore, compared with the first two kinds of systems, the structure of virtual open surgery emulators is most complicated. This kind of emulator is now the mainstream of virtual surgery research. The researchers in INRIA developed a virtual liver cutting operation system (Ayache, 1999) based with force feedback devices. Tokyo Jikei Medical University in Japan developed human living virtual surgery system based on sphere-filled model (Suzuki & Hattori, 2008), the system simulated the interactive manipulations of lifting, pressing and tissue cutting. NRC developed a neurosurgical virtual surgical simulator named NeuroTouch (Delorme, Laroche, Diraddo & Del Maestro, 2012), which reconstructed a 3-D high resolution human brain model based on MRI images, the surgeons can train the cutting operations of brain tumour by manipulating mechanical arms. In most Chinese universities and institutes, the medical VR research work mainly focuses on virtual open surgery emulator. PLA General Hospital worked together with University of Defense Technology (Tan, Guo, Wang, Wang & Wu, 2001), and adopted VR technology and force feedback devices to develop a virtual rhinoscope surgery simulation training system, which provides training simulation of actual conchoscope operations for interns. Southern Medical University and South China Normal University (Fang, Wu & Bao, 2009) developed the abdominal medical image processing system cooperatively, surgeons can use the system to train the operations of cutting, clamping and suture with realistic haptic sense. Tianjin University explored virtual vascular suture simulation system (Zeng, Xu & Yue, 2006) for surgical planning and doctor training, the system consisted of PHANTOM Desktop interactive device and matched GHOST SDK, and was able to simulate microsurgical vascular puncture manipulation with haptic sensor successfully. The researchers in Beijing University of Aeronautics and Astronautics explored a virtual dental surgery training system (Wang, Zhang & Wang, 2004) with Omega 3 haptic interface device of Force Dimension company and PHANTOM desktop double master manipulators of SensAble company, which provided users with realistic force feedback effect. Nanchang University developed a virtual neurosurgical simulation system (Xu, 2010) based on '863' Program of China, which provided a lifelike simulation environment of meningioma surgery to train residents and interns.

3. Future development of VR in medicine

As a technology of multi-disciplinary integration, VR has enormous development potentials and a broad application prospect in various fields. This paper briefly summarises VR applications in medicine field from two aspects. First, virtual anatomy is applied in medical theoretical teaching as a significant innovation to provide students stereo and realistic visual senses, which greatly improves the teaching effects. And second, VRSS plays an important role in the clinical practice training of residents and interns, which provides surgeons a vivid simulation platform for training operation manipulations such as injection, endoscopy surgery, open surgery and so on.

At present, the application of VR in education field is still in its infancy, there are still many unresolved problems and unconquered technical difficulties. However, with the explosive development of VR technology, it is going to be a much greater revolution in medical education field, the economic and time cost of medical education and training will be greatly reduced, and all these will finally accelerate the development of medical services in China. The future development direction of VR is augmented reality (VR), which will mix up the virtual models with the real environment and provides medical students more real immersive visual, auditory and haptic senses in classroom and clinical practice training.

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